1.0 Introduction

Aluminothermic welding has been applied for a century for the joining of rails, however defects do still occur in aluminothermic welds. These are generally due to poor set up and preparation and also due to inadequate attention to detail. The following list of defects in aluminothermic welds with causes of the defect and hints on avoiding the defects has been compiled to assist the personnel involved in performing aluminothermic welds to have a better understanding of the causes of defects in an effort to reduce or hopefully eliminate aluminothermic weld defects and increase the integrity of rail welds.

2.0 Welding procedures

Rigorous adherence to the qualified welding procedure by welding personnel which are qualified to that procedure when executing aluminothermic welds is essential to ensure weld defects are not randomly introduced. The necessary care needs to be taken in each of the following areas:

- Rail end preparation;
- Mould fitting and alignment;
- Luting;
- Preheater alignment;
- Preheating;
- Crucible cleaning and preheating for multi-use crucibles;
- Correct portion selection.

3.0 Aluminothermic weld defect types causes and rectification

3.1 Black holes

An isolated gas pore in the riser of a weld is known as a “black hole”. The name originated from its characteristic appearance as shown in figure 1

Figure 1. Typical black hole

Black holes have been a major cause for rejection of welds, however there are very few recorded cases of failure initiating from a black hole as the isolated hole is generally fairly shallow and rounded. The defect is caused by gas passing through the weld during solidification. Gas source is from steam from the sealing material under the rail foot. Using narrower than normal weld widths increases risk of getting black holes

To minimise the occurrence of black holes:

- Use a railhead gap > 24 mm, adjusting the weld gap if required;
- Ensure that the luting material is not too wet;
- Observe all checks and procedures to control porosity;
- Ensure that preheating is performed correctly.

3.2 Slag inclusions

Slag inclusions are caused by;

- Not cleaning or inadequate cleaning of the crucible where multi-use crucibles are used;
- Poor flame cut surfaces with incorrect cutting parameters producing gouges or with inadequate removal of slag and oxide can case slag inclusions on the weld fusion zone or cause slag to be taken up in the weld metal;
- Inadequate preheat can promote the formation of slag inclusions in that slag gets trapped in the weld;
- Incorrect joint gaps affect the flow of the metal in the mould and can also promote slag inclusions;
- Cold pour or early pour of the aluminothermic portion can also cause slag inclusions

3.3 Weld shrinkage or tearing

Weld shrinkage or tearing are the same type of defect and generally occurs in the weld foot area as this is the last portion of the weld to solidify as shown in figure 2

Figure 2 Weld shrinkage/tearing

The causes of shrinkage /tearing are due to one or more of the following:

- Insufficient pre heat prior to welding;
- Slip on the tensor jaws;
- Not using tensors or poor set up of the tensors;
- Other work on track causing undue stresses on cooling welds;
- Change in temperature can cause stress on solidifying welds;
- Unclamping of the aluminothermic weld before solidification is complete;
- Passing of traffic while the weld is still too hot.

The weld should be allowed to cool down to below 350°C to allow it to develop sufficient strength before any loads are applied. Hot tensile tests have shown that approximately 80 % of the strength is developed at 350°C.
Thermocouple measurements have shown that for welds to cool down to below 350°C takes approximately 24 minutes.

3.4 Sand Burns

Sand burns occur on the rail surface where luting sand has come in contact with the preheating flame or the pouring steel. The sand is heated to temperature where vitrification of the luting material takes place and marks are burned into the surface of the rail. These defects are normally removed during the grinding operation. Figure 3 shows sand burns remaining after the weld has been ground. In some cases repair welding may be required

Figure 3 Sand burns on ground rail surface

3.5 Lack of Fusion

Lack of fusion occurs when the weld fails to fuse into one side or part of the rail as shown in figure 4

Figure 4 Lack of fusion in the rail foot

Lack of fusion defects can result from any one or a combination of the following causes:

- Mould misalignment;
- Cold pour or late pour;
- Inadequate preheat of the joint;
- Poor burner alignment causing uneven preheating of the two rail ends;
- Incorrect gas pressures on the pre heater;
- Incorrect weld gap;
- Incorrect portion size for the size of rail;
- Incorrect mould size being used on the joint.

3.6 Mould misalignment

Mould misalignment can case the weld to not fuse in one or more areas of the rail and figure 5 shows an area where the rail foot has not been incorporated into the weld (the original flame cut surface can still be seen)

Figure 5. Total lack of fusion at rail foot due to mould misalignment

Mould misalignment is due to poor set up, location and fitting of the moulds on the joint. It is essential that the moulds are aligned vertically and are centered on the weld centre line.

3.7 Flashing or finning of the welds

Flashing or finning of aluminothermic welds is where molten metal flows between the mould and the rail and forms a fin or flash as shown in figure 6. It is often not considered as a serious defect, however latest experience has shown that particularly on heavy haul track with high axle loads, a large number of rapid failures have resulted from these defects.

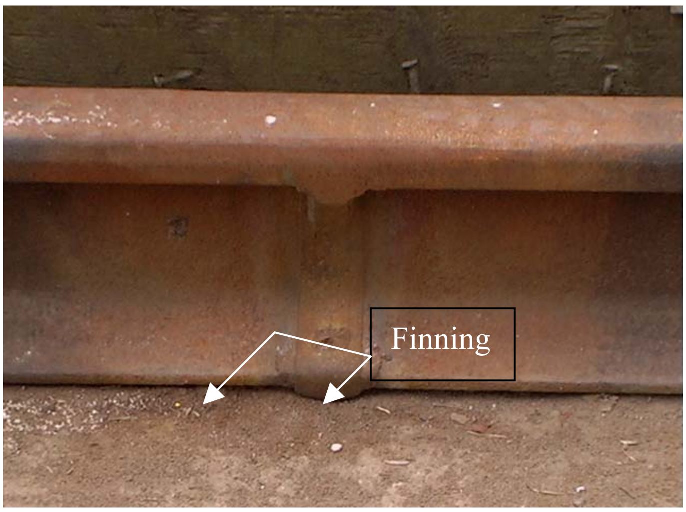

Figure 6. Flashing/finning at the weld edges on the rail foot

3.8 Porosity

Porosity is mainly located within the weld and is often not visible on the outer surface of the weld. Particularly when a large number of pores are present (as shown in figure 7), the strength of the weld can be significantly reduced.

Figure 7. Gross porosity in the weld

Porosity in aluminothermic welds is caused by any one or more of the following factors:

- Inadequate or no preheating of the crucible in multi use crucibles;
- Wet luting material;
- Insufficient preheat of the joint;
- Wrong portion size for the rail size;
- Wet or contaminated moulds;
- Welding in the rain.

4.0 Conclusion

If aluminothermic welders are properly trained and qualified, and the necessary care and attention is followed with welds being done rigorously to the procedure, weld defects can be eliminated.
This will significantly increase the reliability of aluminothermic welding and can reduce the need for subsequent non-destructive testing.
Avoidance of weld defects provides numerous advantages:

- Elimination of costly field repairs;
- Increased integrity of track;
- Reduced incidences of track failures.

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NDNP TECHNOLOGY DIFFUSION ACTIVITY # 27	WTIA Welding Technology Institute of Australia ABN 69 003 696 526 **NATIONAL DIFFUSION NETWORKS PROJECT** **TECHNOLOGY QUESTIONNAIRE** **Rail Group** **"Aluminothermic Weld Defects"**	**Document No:** 9.4.1 **Revision No:** Rev 0 **Page 1 of 2** **Date:** 30 may 2005

As part of the WTIA National Diffusion Networks Project the Rail Industry Sector has identified the need for reducing aluminothermic weld defects. The WTIA has prepared a Technical Guidance Note "Aluminothermic Weld Defects" that explains how to produce sound welds and eliminate weld repairs. As a valued technology expert in this area we would like you to be part of the Technology Expert Group to review this note. Please complete this questionnaire so that we can gauge the success of meeting this need.

Objective 1: Identify the need for quality cutting of rail.

Aluminothermic welding is a standard method for joining rail. Weld defects do occur from time to time and this guidance note is intended to provide the Rail Industry with information on producing sound aluminothermic welds without defects. How well does the document achieve these aims?

poor ☐ average ☐ good ☐ very good ☐

Comments: ____________________

Objective 2: Identify appropriate technology receptors

This document was written for Maintenance Engineers, Maintenance Contractors and Welding Coordinators in the Rail Industry. Are these people the appropriate individuals we should be targeting?

yes ☐ no ☐

What other types of companies and/or personnel do you suggest we target? ____________________

____

Objective 3: Identify current best practice for cutting rail

The document was written to reflect current best practice for avoiding defects in aluminothermic welds. Do you envisage opportunities for the use of this practice in industry?

yes ☐ no ☐

If yes, what and where, if no why not? ____________________

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Objective 4: Is the information provided clear, concise and accurate?

yes ☐ no ☐

If not, why? ____________________

Objective 5: Broad dissemination of technology to the Rail Industry

Please indicate how best to disseminate this Technical Guidance Note to the appropriate Industry Recipients

Free Website Download ☐ Poster☐ Pocket Guide ☐ Pamphlet ☐

If poster, what size? A1 ☐ A2☐ A3 ☐ Laminated ☐ What selling price? $

If a pocket guide, what selling price? $

Other format? ____________________

Objective 6: Continuous Improvement

Please Identify areas where the document can be improved or return the document with your recommended additions/amendments. Alternatively, please use the area below to provide any additional comments.

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*Respondents Name:*________________*Company:* _________________*Phone:* ____________________

Fax: ____________________________*Email:* ___________________________*Date:* ______________

Please Fax (02 9748 2858) or E-mail (info@wtia.com.au) with your response.

The WTIA has joined forces with industry and government to create a 3.5 million dollar Technology Support Centres Network. This network will assist industry to identify and exploit world's best technology and manufacturing methods to establish a vibrant Australian industry beyond 2006. Together we will be implementing a step by step process which will lead to ongoing viability and greater profitability for all concerned:

(1) Determine your technological and manufacturing needs;
(2) Identify world's best practice;
(3) Draw upon the network to implement world's best practice at your site